COmpact Propulsion Engine Optimized with Waste HEat Recovery (CO2-POWER)

Ram Ranjan, Raytheon Technologies Research Center

Range Extenders for Electric Aviation with Low Carbon and High Efficiency (REEACH)

Project Vision

Maximize gas turbine efficiency with low weight using a supercritical CO2 (sCO2) waste heat recovery system
>10% net efficiency increase over SOA with comparable power density

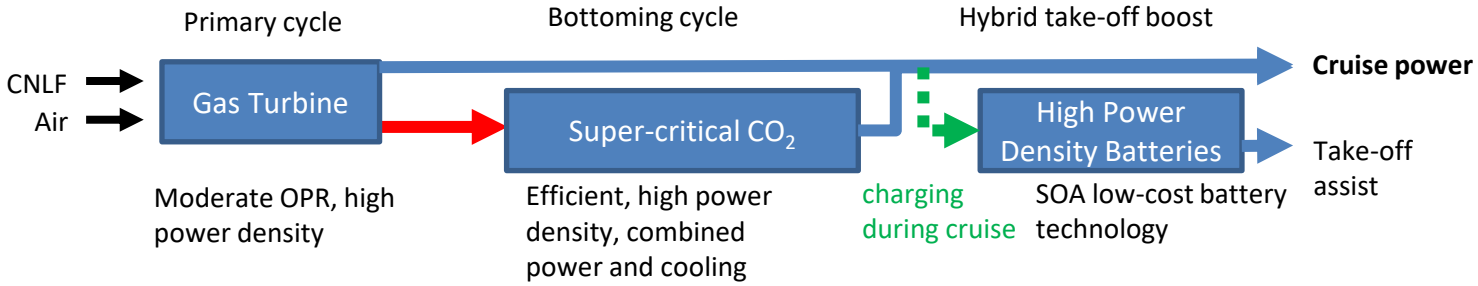
REEACH / ASCEND / CABLES
Annual Program Review Meeting
June 28-30, 2022

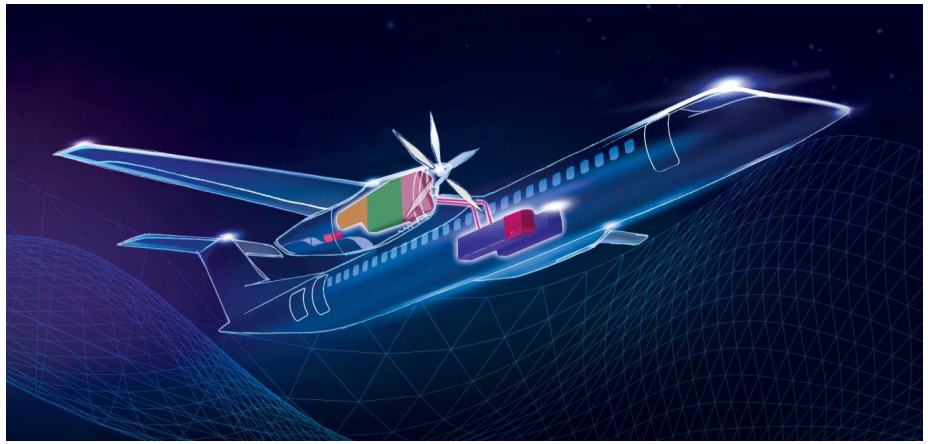
REEACH Phase 1 Project Overview

Fed. funding:	$2.8M
Length	24 mo.

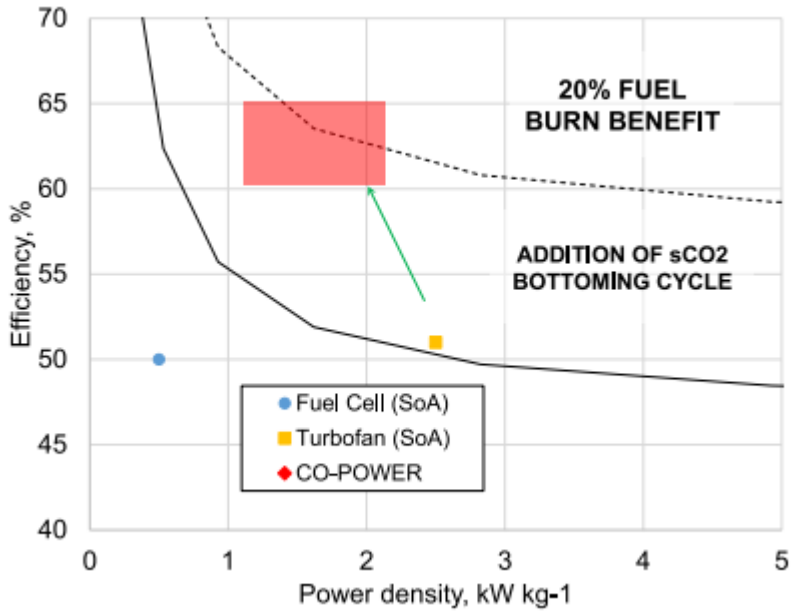
Context/history of the project

- RTRC has been developing compact sCO2 heat exchanger technology in HITEMMP program
- System works with any CNLF
- RTX leading research in electrified propulsion system





RTX's hybrid electric propulsion demonstrator program



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Team

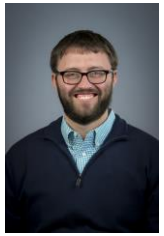
Team member	Location	Role in project
Raytheon Technologies Research Center	East Hartford, CT	Requirements, system architecture design, component and system validation testing
Pratt & Whitney	East Hartford, CT	Gas turbine design, commercialization
Collins Aerospace	Rockford, IL	Electrical system design, commercialization
Oregon State University	Corvallis, OR	sCO2 cooling of electrical components

- Multi-disciplinary team with domain leadership
- All team members have executed ARPA-E programs in the past


Ram Ranjan
RTRC


Brent Staubach
P&W


Andreas Koenig
Collins


Joshua Gess
OSU

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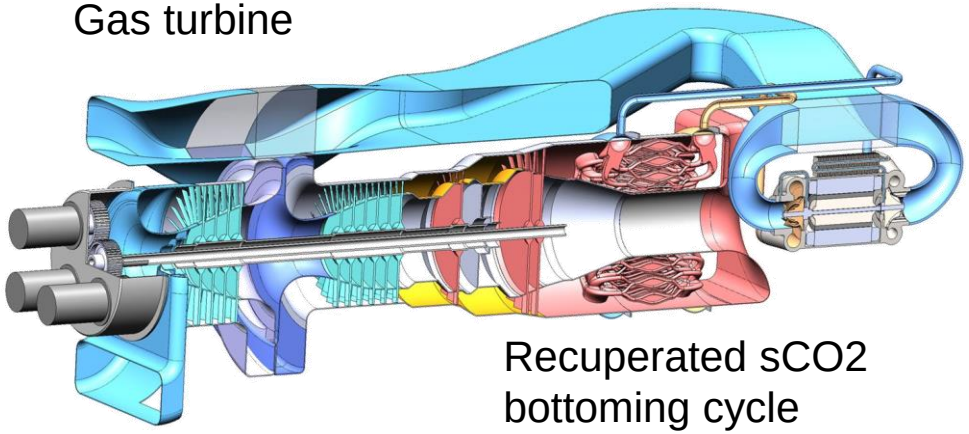
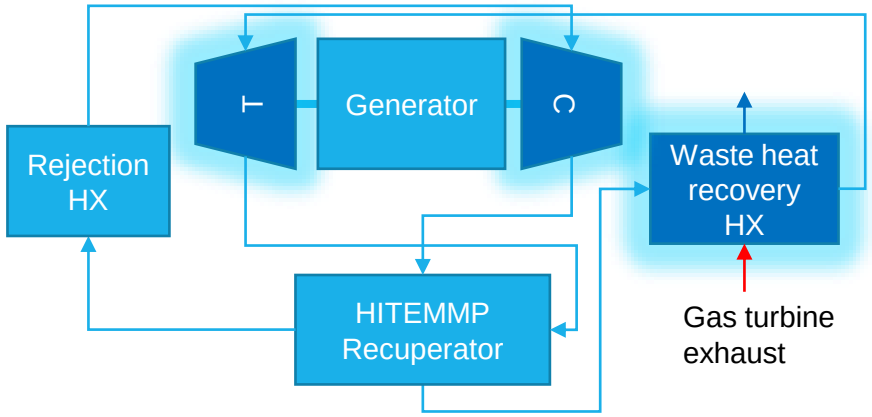
Innovation

Gas turbine



Recuperated sCO2 bottoming cycle



System performance w.r.t. SOA

Energy storage and power generation metric	ARPA-e goal	Baseline	CO-POWER
Total ESPG specific energy, incl. fuel wt. (kWh/kg):	3.0 kWh/kg	3.50	3.50 ↔ 4.50
ESPG specific peak power, incl. fuel wt. (kW/kg):	0.75 kW/kg	0.88	0.80 ↔ 1.20
ESPG total capital cost, per deliv. energy ($/kW):	$1000/kW	341	350 ↔ 1000
ESPG delivered energy (incl. effic.) cost ($/kWh):	$0.15/kWh	0.152	0.16 ↔ 0.15

Compact high pressure HX technology

Barber-Nichols S-CO2 turbine wheel
Photo: Sandia National Laboratory

High speed and high efficiency turbomachinery

Sub-scale and full-scale testing

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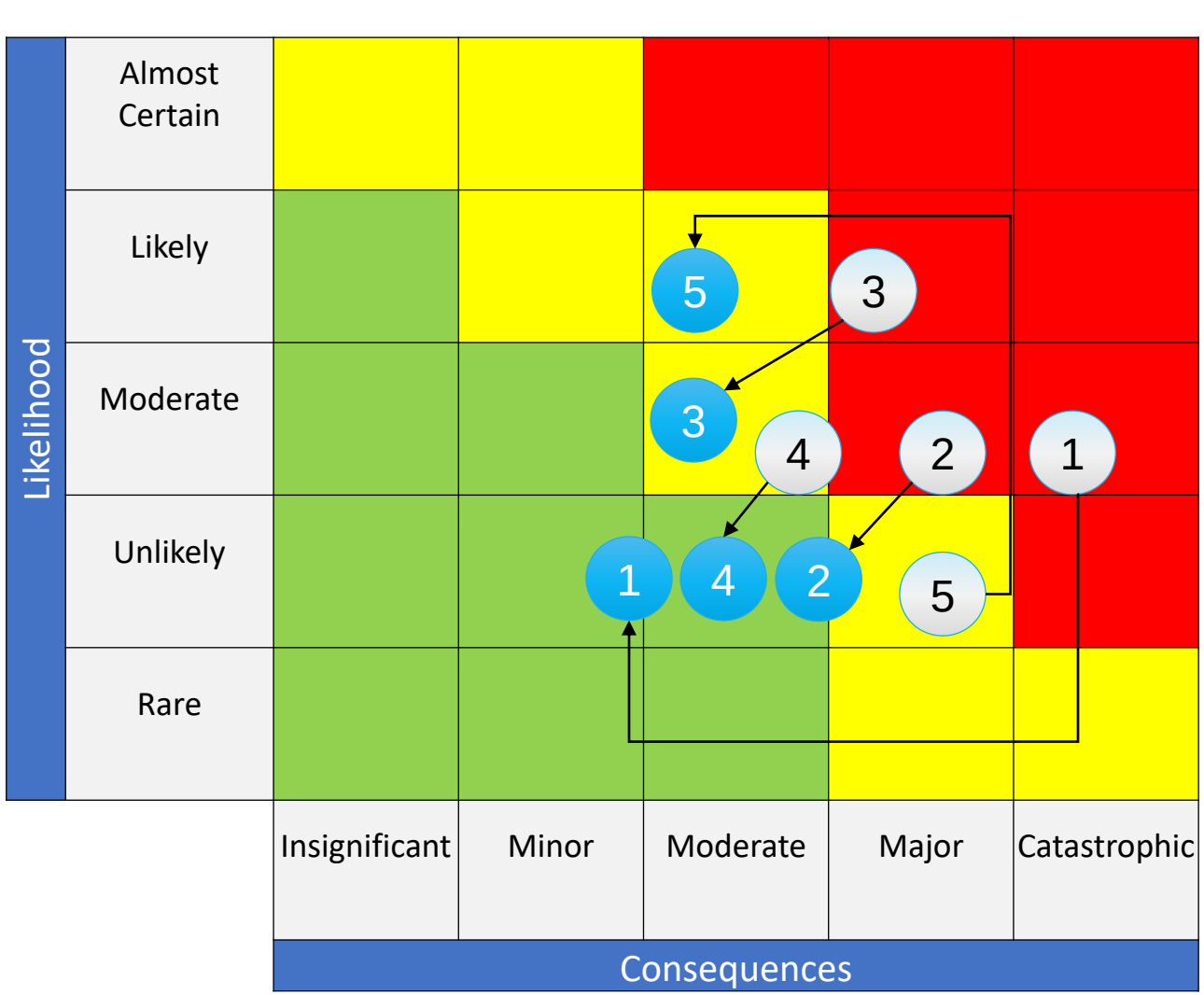
Risk Update



X Now

X Start of project

Risk	#
HX weight & durability	1
Turbomachinery efficiency	2
CO2 leakage in components	3
System performance across flight envelope	4
System cost higher than SOA	5

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Task Outline & Technical Objectives

Critical Risk Reduction
12 months

Sub-scale Component Demonstrations
6 months

Phase 1 sCO2 Cycle Power Gen Demonstration
6 months

Phase 2: Integrated gas turbine-sCO2 cycle demonstration
12 months

Major Tasks and Go / No-Gos
Task 1: ESPG system design and refinement
Go/No-Go: Full system detailed design review
Task 2: Waste heat recovery HX development
Task 3: sCO2 turbomachinery development
Task 4: sCO2 turbogenerator development
Task 5: sCO2 loop integration and power generation demo
Go/No-Go: sCO2 power gen demo & ESPG system review
Task 6: Technology to Market
Task 7: Program Management (TRL/MRL Review)

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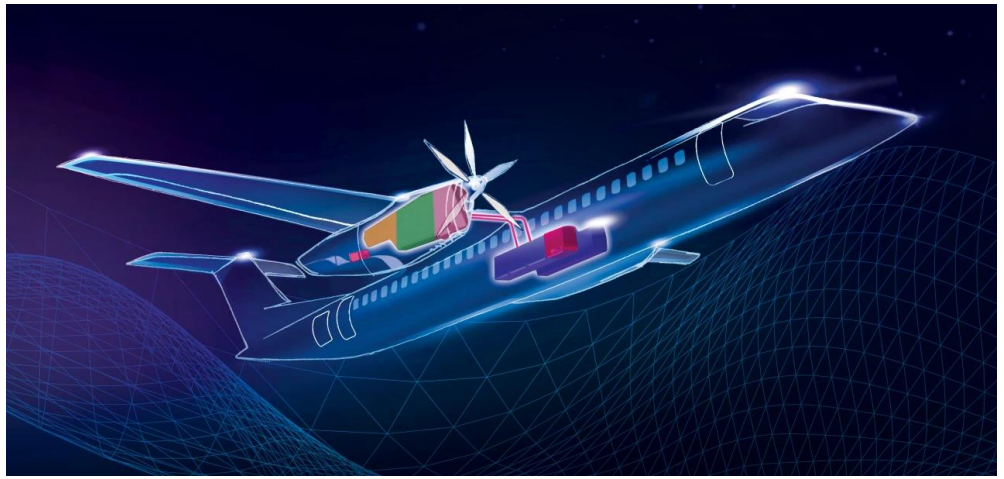
Technology-to-Market Approach

- Technology-to-Market strategy is focusing on hybrid aviation applications for RTX business units Collins Aerospace and Pratt & Whitney.
- General application markets are waste heat recovery and primary power generation on aircraft.
- Other application includes ground-based high efficiency power generation systems (modular nuclear, solar, etc.)
- Anticipated first markets
  - Aerospace power generation applications, TRL5-6 demo in Phase 2 program (2024)
- Key to aerospace commercialization: efficiency, durability and power density



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Q & A

https://arpa-e.energy.gov